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Future Prospects and Policy Implications for Biodiesel Production in Malaysia: A System Dynamics Approach

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Abstract: *Malaysia targets biodiesel as a renewable energy source to achieve its low carbon economy. This paper examines biodiesel and crude palm oil productions in Malaysia using a system dynamics approach. It aims to develop a model for the Malaysian biodiesel industry by capturing the relationship between major elements in the system such as supply, demand, inventory and price. The system dynamics approach is used as it enables one to capture feedback relationships, non-linearity, and delay in commodity markets including palm oil. The model has been simulated for 44 years, from 1982 to 2025 and the results indicate that crude palm oil demand for biodiesel will double requiring better strategy and policies to manage the stock and production of palm oil. Given biodiesel production in Malaysia is largely dependent on palm oil, Malaysia needs policies for development strategies of biodiesel production for coming years to meet its increasing demand.*

Keywords: Biodiesel, crude oil, crude palm oil, simulation, system dynamics
JEL classification: E3, Q1, Q4

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1. Introduction

The world is moving towards a low emission energy future driven by growing energy demand, limited fossil fuel reserves (such as coal, petroleum and natural gas), and climate change (Thangaveluet, Khambadkone, & Karimi, 2015). Renewable energy resources are increasingly being considered because of their availability resources and their environmental friendly characteristics (Hosseini & Wahid, 2012).

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Energy consumption in Malaysia has been growing at a fast rate with 29,698 kilotonne of oil equivalent (ktoe) consumed in 2000 and which increased to 51,583 ktoe in 2013, a jump of 73.5% (Energy Commission, 2015). However, non-renewable energy sources are depleting rapidly due to increasing demand in almost every sector (Yusoff, Abdullah, Sultana, & Ahmad, 2013). To address energy shortage and environmental issues caused by burning fossil fuels, the government of Malaysia has implemented a new energy policy that emphasises utilising palm oil as feedstock for biodiesel.

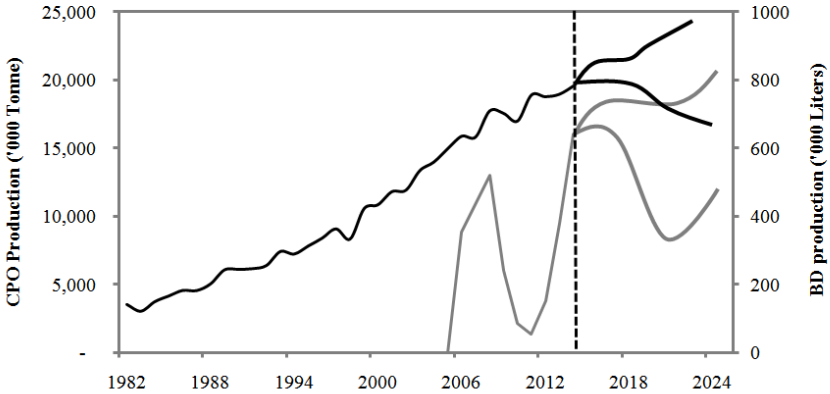
In 2006, Malaysia launched its first biodiesel policy aiming to develop biofuel technology in 2007, Parliament passed the Biofuel Industry Act, which included provisions for the Ministry of Plantation Industries and Commodities (MPIC) to implement a biodiesel blend mandate (Wahab, 2014). The current mandatory share of biodiesel is 5% which refers to a blend of 5% palm methyl ester and 95% petroleum based diesel.

The main purpose of this paper is to develop an understanding of Malaysian biodiesel industry using a systems approach not found in the feasibility studies. It provides insights into the biodiesel industry in understanding the dynamics that are likely to dominate this industry over the next decades. Therefore, this paper makes a major contribution to research on biodiesel production by proposing a holistic view that might influence policy and decisions to help the industry grow.

The palm oil industry has significant economic advantages thus requiring a careful understanding of the market behaviour of its key variables. Hence, this paper explores the dynamics that could lead to different growth patterns (Figure 1). It also seeks to answer the following research questions: will the production capacity grow steadily, or will it encounter “overshoot and collapse” cycles? Will exponential growth occur in the near future because of unforeseen market shift? Under what circumstances might each of these trends be realised? The growth behaviours that the model enables us visualise are not forecasts of the future but are starting points for a discussion of possible outcomes.

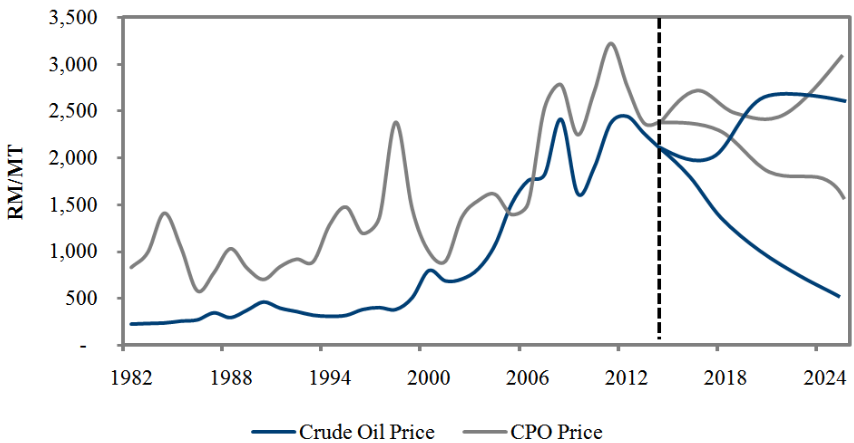
More specifically, this paper investigates the possible future behaviours of biodiesel and crude palm oil (CPO) productions in Malaysia for the next ten years using a system dynamics approach. It simulates the future behaviour of CPO demand for biodiesel productions with regards to changes in CPO and crude oil prices (Figure 2). It also examines the impact of higher efficiency in fresh fruit bunch (FFB) harvesting mechanism in the volume of CPO production.

Figure 1: Scenarios of possible future behaviour of CPO and biodiesel productions



Source: Malaysian Palm oil Board [MPOB], (2015); Wahab (2013).

Figure 2: Scenarios of possible future behaviours of CPO and crude oil prices



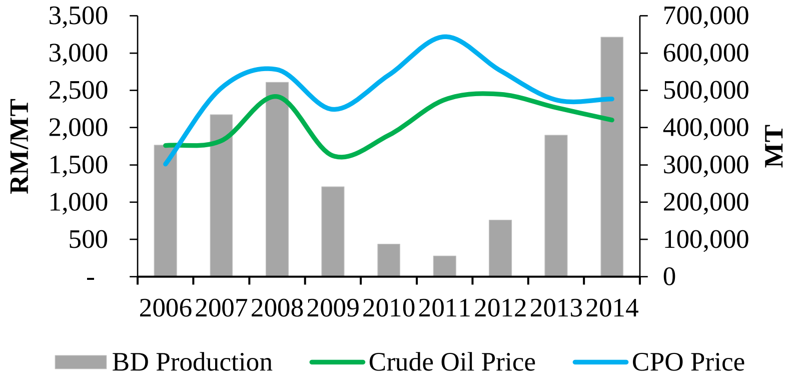
Source: MPOB (2015); Wahab (2013).

2. Palm Oil and Biodiesel Productions

The production of biodiesel in Malaysia began in late 2005 when, for the first time in three decades, the price of CPO dipped below that of crude oil, as seen in Figure 3. In 2005, the crude oil price dramatically increased by about 30% from USD 37.8/barrel in 2004 to USD 53.4/barrel in 2005 and continued to increase in the following years (Malaysia Energy Information Hub, 2012).

Meanwhile, the price of CPO decreased by 15.5% from RM 1,610/mt to RM 1,349/mt during the same period (MPOB, 2012). However, the advent of this new product coupled with other traditional economic factors pushed the price of CPO up again by 40%, increasing sharply from RM 1,511/mt in 2006 to RM 2,531/mt in 2007 (Abdullah, Abas, and Ayatollah, 2007). In the 2000s, palm oil and crude oil appeared to experience similar price movement which indicates a positive linkage between the two prices.

Figure 3: Biodiesel production (Metric Ton), CPO and crude oil prices (RM per Metric Ton), 2006-2014



Source: MPOB (2015); Wahab (2013).

2.1 CPO Production

Table 1 shows the oil palm planted area and production of CPO in Sabah, Sarawak, and Peninsular Malaysia. The planted area and CPO production in Sabah has increased by 93.4% and 97% from 93,967 ha and 156,471 mt in 1980 to 1.4 mn ha and 5.5 mn mt in 2012 respectively. Similarly, plantation and production in Sarawak show significant increase of 97% and 99% during the same period respectively. In Peninsular Malaysia, planted area and CPO production has increased from 906,590 ha and 2.4 mn mt in 1980 to 2.5 mn ha and 10.3 mn mt in 2012, suggesting an increase of 64% and 76% respectively. The total production of CPO in Malaysia has increased by 86% from 2.5 mn mt in 1980 to about 18.8 mn mt in 2012. The annual growth of CPO production has changed over the last three decades indicating an average growth of 7.7% in 1980s, 5.2% in 1990s, and 4.2% in 2000s.

Table 1: The palm planted area ('000 ha) and production of CPO ('000 mt) in Sabah, Sarawak, and Peninsular Malaysia, 1980-2012

Year	Sabah		Sarawak		Peninsular Malaysia	
	Planted Area	**CPO Production**	**Planted Area**	**CPO Production**	**Planted Area**	**CPO Production**
1980	94	156	23	22	907	2,394
1985	162	285	29	49	1,292	3,801
1990	276	679	55	108	1,698	5,308
1995	518	1,494	119	222	1,903	6,095
2000	1,001	3,110	330	520	2,046	7,212
2005	1,209	5,334	543	1,337	2,299	8,291
2010	1,410	5,316	919	2,180	2,525	9,498
2011	1,432	5,843	1,022	2,696	2,547	10,373
2012	1,443	5,543	1,076	2,923	2,558	10,320

Source: MPIC (2005); MPOB (2012).

2.2 CPO and Crude Oil Prices

The price of CPO was subjected to wild fluctuations during the last decades. The CPO price has increased from RM 701/mt in 1990 to RM 2,384/mt in 2014, an increase of 70% (MPOB, 2015). The price increase is attributed to changes in the world palm oil and soybean oil prices as well as an increase in the demand for palm oil products. The price of crude oil has also risen sharply from USD 23/barrel in 1990 to USD 90.9/barrel in 2014, indicating an increase of 74%. As forecasted by the World Bank (2015), the price of crude oil is expected to decrease by about 28% from USD 90.9/barrel in 2014 to 64.6/barrel in 2020 and an expected increase of 22% reaching USD 82.9/barrel in 2025.

2.3 Biodiesel Production

The rapid increase in crude oil price above the price levels of vegetable oils beginning in 2004, provided the impetus for turning vegetable oils into biodiesel for transportation fuel. Accordingly, palm oil feed stocks are considered as an alternative source of energy to eliminate the use of fossil fuel, with Malaysia and Indonesia having the potential to capture the biggest market shares. Arshad (2008) argues that Malaysia and Indonesia have the potential to capture 20% of the world's biofuel if the price of CPO remains attractive compared with that of crude oil.

Malaysia began producing biodiesel commercially at end-2005 when the price of CPO decreased 15.5% compared with its previous year. Malaysia's

National Biofuel Policy introduced in August 2005 aims to position Malaysia as a global biodiesel producer. The primary goals of the policy are to expand and diversify the market for crude palm oil, to increase the export of biodiesel and biofuel feed stocks, to help alleviate rural poverty, and help address long-term domestic energy needs (Hameed & Arshad, 2010). The mandatory biodiesel blending was enforced on June 2011 which requires diesel to contain 5% biodiesel. It is expected that the share of biodiesel will increases from 5% to 10% in the future (Applanaidu, Arshad, Shamsudin, & Yusop 2010).

However, biodiesel production in Malaysia is significantly under-developed. The attempts by the Malaysian government to increase its use of biofuels and to expand the market both domestically and internationally have not been successful due to the unfavourable market conditions including high crude palm oil prices and the delay in implementing biodiesel blend policy from 2008 to June 2011. Table 2 shows that there are 29 bio-refineries in Malaysia with an estimated capacity to produce 2.74 mn litres of biodiesel. However, the quantity of biodiesel produced is less than 25% of the maximum capacity. The CPO used in biodiesel production was 591,000 mt in 2014, about 2% of total CPO production in Malaysia.

Table 2: Biodiesel production capacity and CPO used

Year	No. of Bio-refineries	Nameplate Capacity ('000 Litres)	Capacity Use (%)	BD Production ('000 Litres)	CPO Use in BD ('000 MT)	CPO Price (RM/ MT)	Crude oil Price (RM/ Barrel)
2006	8	530	66.60%	353,275	325	1,511	1,760
2007	15	1,121	38.80%	434,800	400	2,531	1,824
2008	23	2,019	25.80%	521,760	480	2,778	2,416
2009	27	2,610	9.20%	241,314	222	2,245	1,622
2010	28	2,746	3.20%	86,960	80	2,705	1,898
2011	28	2,746	2.00%	55,437	51	3,219	2,373
2012	29	2,746	5.50%	152,180	140	2,764	2,447
2013	29	2,746	13.80%	379,363	349	2,371	2,268
2014	29	2,746	23.40%	642,417	591	2,384	2,101

Source: Wahab (2013).

3. Methodology

3.1 Data Source

This paper employs system dynamics approach to examine the future behaviours of CPO and biodiesel productions in Malaysia using secondary data (from 1982 until 2012) obtained from Malaysian Palm Oil Board and Ministry of Plantation Industries and Commodities.

3.2 System Dynamic Approach

System dynamics is a method to describe, model, simulate and analyse dynamically complex systems in terms of the processes, information, organisational boundaries and strategies (Pruyt, 2013). It is used to examine the relationship between variables, non-linearity, and delays that exist in systems (Richardson & Pugh, 1985). As stated by Sterman (2000), system dynamics is concerned with dynamic complexity, sources of policy resistance, and the design of effective policies.

In system dynamics, the model building process consists of problem articulation, dynamic hypothesis, formulation, testing and policy formulation and evaluation (Sterman, 2000). In the problem articulation stage, problem statement is clarified. All information about the behaviour of the problem is important including historical behaviour of key concepts and variables. Data is used to investigate the problem and to shape the hypothesis as soon as the problem statement has been identified and described. . A causal mapping is then developed based on the hypothesis, key variables, reference and other accessible data using boundary diagrams, subsystem diagrams, causal loop diagrams and other helpful tools. Boundary and subsystem diagrams show the structure and boundaries of the model; however, they do not show how the variables are interrelated. The arrows show the link among variables based on to their effect on each other. Thus, causal loop diagrams are helpful for mapping feedback structure (Sterman, 2000).

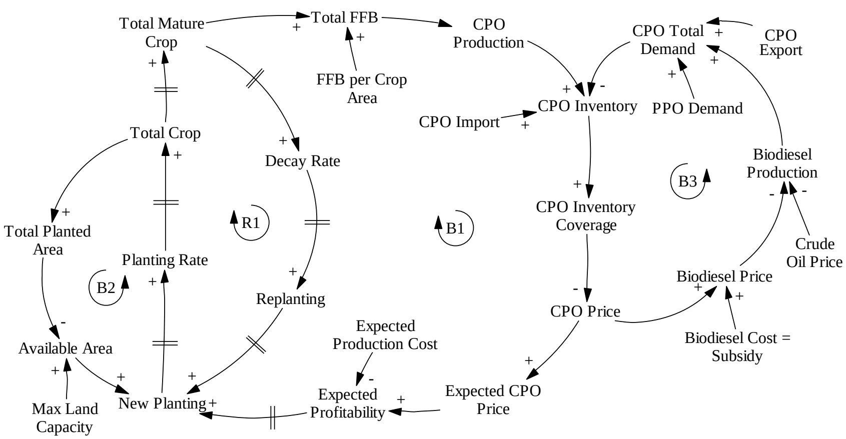
The formulation stage concerns with the equations used in the model and converting causal loop diagrams into a stock and flow diagram. These processes are usually done by using specific software such as Stella, Vensim and others. Once the conversion is completed, equations among variables are set. A stock is a term that refers to variables that accumulate or deplete over time. Inflow or outflow is an indicator of change in a stock. The simulation of the model begins with the equations and comparison of the simulation results of the model to the real behaviour of the system. In addition to replication of historical data, dimensional consistency check must be conducted to avoid errors. As soon as the model replicates same structural behaviour with the actual data, it must be checked for sensitivity and extreme conditions tested. Once certainty in the structure and behaviour of the model is obtained, the latter can be utilised to design and evaluate policies.

Causal loop diagrams (CLD) and stock and flow (S&F) diagrams are two commonly used diagrams in system dynamics modelling. Basically, CLD is the qualitative presentation of a system behaviour. It shows the feedback structure of a system and the relationship between selected variables. The modelling process progresses with the CLD model being converted into a physical structure known as stock and flow diagram. The S&F diagram is the quantitative presentation of the system behaviour defined by equations, parameters, and initial conditions.

Sterman (2000) presents a generic structure for commodity markets, adapted from Meadows (1970) who developed the initial feedback structure for commodity cycles and applied it to livestock. Generic commodity market model involves: Supply, demand, price, profitability, cost and other key variables. Generic structure could be applied in developing other commodity models. Arshad, Bala, Alias, and Abdulla (2015) adopted the structure to study boom and bust of cocoa production systems in Malaysia. Ibragimov, Arshad, Kusairi, and Muhammad (2014) used the same technique to examine the impact of CPO export duties on Malaysian palm oil industry. Abdulla, Arshad, Tasrif, Bach, and Mohammadi (2015) studied the Malaysian pepper industry using the same technique. Mohammadi, Arshad, Bala, and Ibragimov (2015) adopted the structure to investigate determinants of the Malaysian palm oil price. The same system structure is utilised in this paper.

Figure 4 presents the CLD for oil palm plantation sector and biodiesel production sector in Malaysia. It consists of three balancing (negative) feedback loops and one reinforcing (positive) feedback loop which are illustrated as follows.

Figure 4: CLD for oil palm plantation and biodiesel sectors



Source: Authors.

CPO Production Loop (B1): as CPO price increases, the expected CPO price and profitability increase which leads to an increase in the total planted area. As mature oil palm areas increase, it leads to higher FFB yields and CPO production. Thus, as CPO production in Malaysia increases, palm oil inventory recovers leading to lower CPO prices.

Land Availability Loop (B2): increase in both total planting areas and planting rate leads to a net decline in new planted area. It is estimated that Malaysia has a maximum land capacity of 5.6 mn hectares. In 2011, oil palm plantation area reached 5 mn hectares (Henriksson, 2012).

Palm Age Profile Loop (R1): rapid growth in new planting rate and total mature crop, decay rate increases which leads to an increase in replanting activities and new planting.

Biodiesel Production Loop (B3): the increase in CPO prices leads to an increase in biodiesel price which results in biodiesel production and total demand for CPO. As demand for CPO declines, CPO inventory expands which leads to lower CPO prices.

Figure 5 presents the S&F diagram associated with CPO and biodiesel productions, using Vensim modelling software. There are four stocks (levels) constituting the palm oil plantation sector: immature crops, young crops, mature crops and old crops. The lifespan of an oil palm tree is between 24 and 32 years. The peak yield of FFB is during the crop's mature age and which gradually declines thereafter. To determine CPO production, FFB/ha/year is multiplied by oil extraction rate (OER).

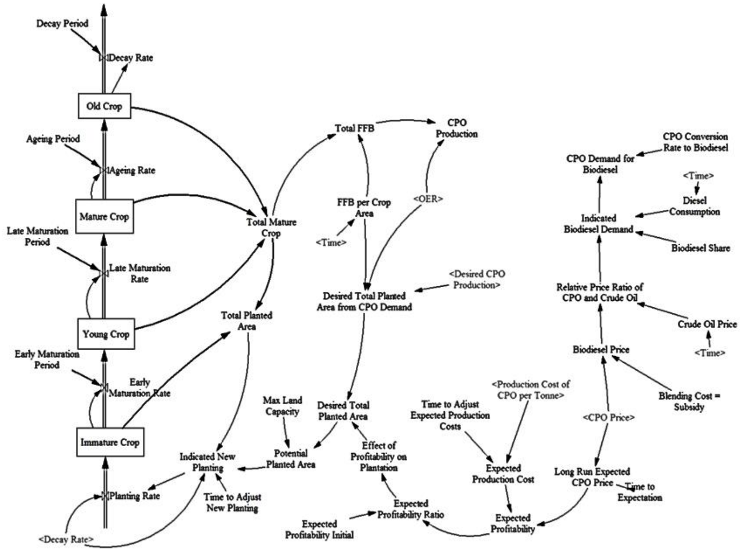
Biodiesel production increases when the price margin between CPO and crude oil prices increases. The current mandatory share of biodiesel is 5% which refers to a blend of 5% palm methyl ester and 95% petroleum based diesel. The conversion rate of CPO to biodiesel is estimated at 0.88 (dimensionless) with a blending cost of about RM80 per tonne or 0.80 cents per litre (Wahab, 2013).

4. Findings and Implications

Model validation is important in detecting the flaws in the system structure. For a start, it is always helpful to compare simulation results with historical behaviours. A sound model should replicate plausible behaviours as discerned from the observed patterns. As seen in figures 6 to 9, simulation results for CPO and biodiesel productions, total mature crop, and CPO price show similar behaviours to the historical data. Statistical tests including RMSPE and inequality statistics were used to build confidence in the model. Test results show no systematic error in the model and the model captures right behaviours.

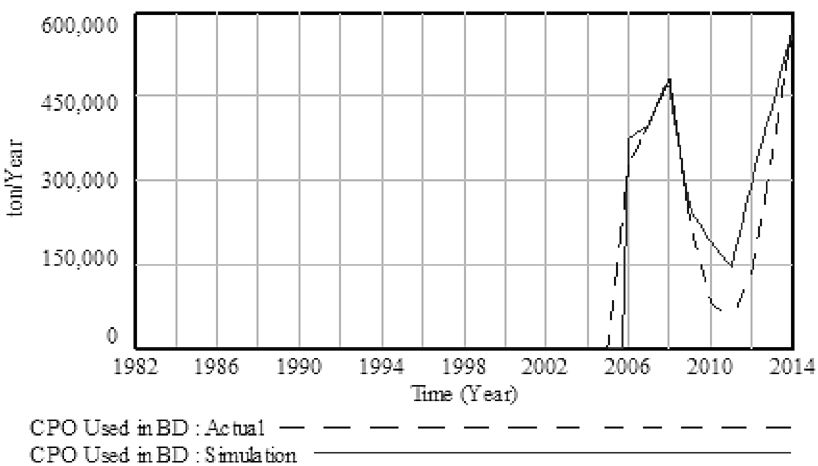
It is necessary to note that the model is not developed for point-by-point prediction; rather, the aim is to study the system behaviours and to obtain an understanding of the market structure.

Figure 5: S&F diagram for CPO and biodiesel production sectors



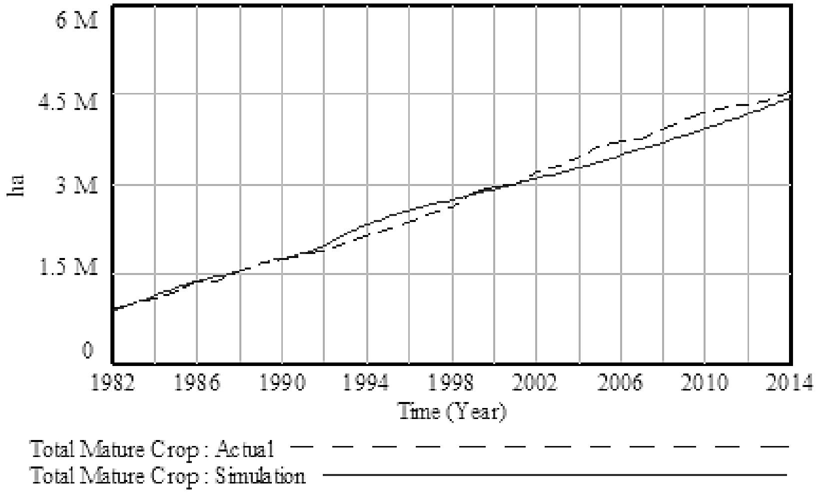
Source: Authors.

Figure 6: Simulation of CPO used in biodiesel production, 1982-2014



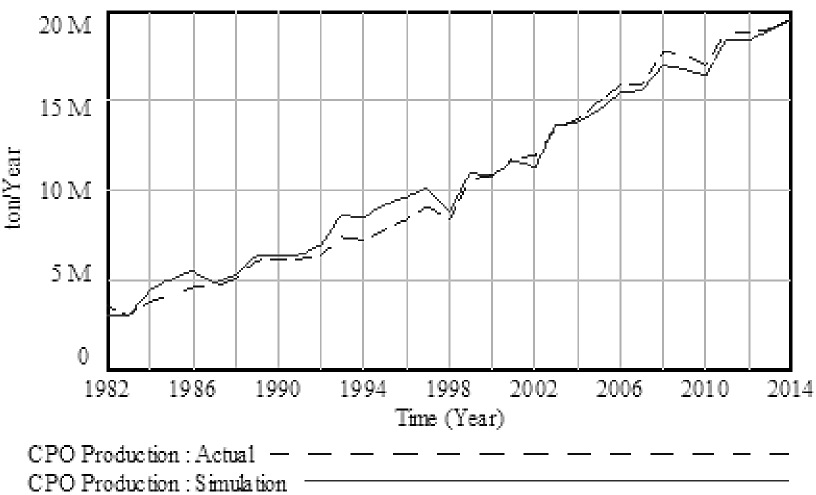
Source: Authors' estimation.

Figure 7: Simulation of total mature crop, 1982-2014



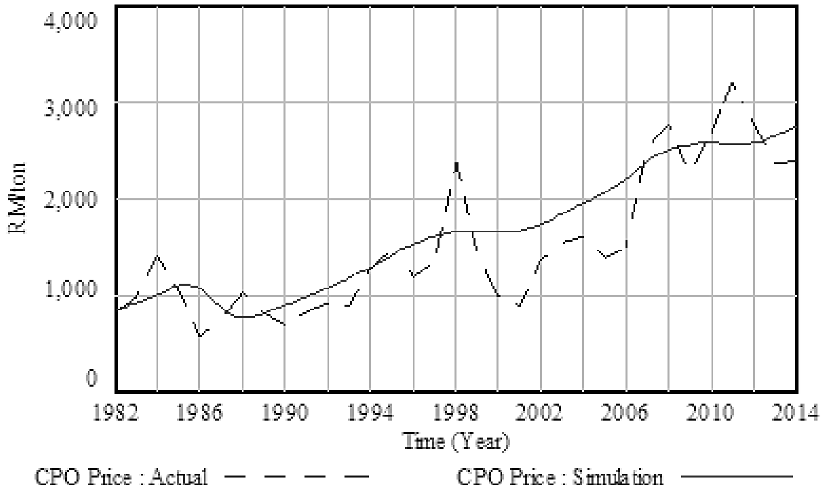
Source: Authors' estimation.

Figure 8: Simulation of CPO production, 1982-2014



Source: Authors' estimation.

Figure 9: Simulation of CPO price, 1982-2014

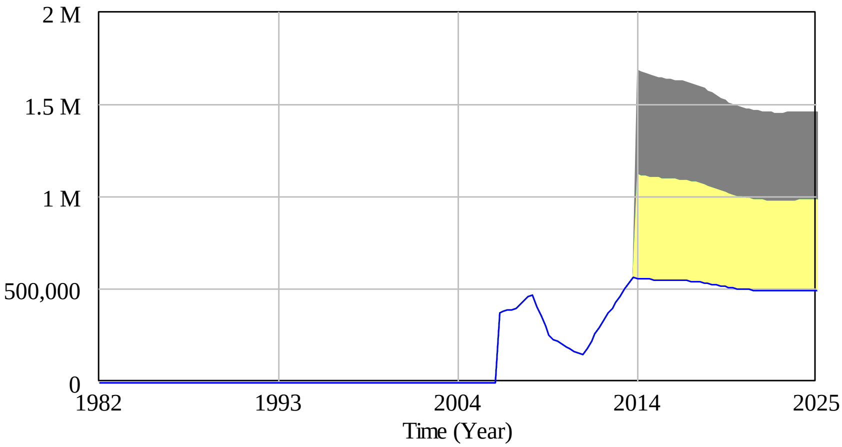


Source: Authors' estimation.

The model aims to examine the possible future behaviour of CPO production and CPO demand for biodiesel production in Malaysia. In the first scenario, blends 10 and 15 of biodiesel were introduced into the system. In the second scenario, FFB yields were increased which can be done by improving harvesting mechanisms.

Simulation results show that the CPO price is expected to increase from RM 2,384/mt in 2014 to RM 3,671/mt in 2025, suggesting an increase of 35%. Using this result and the forecasted crude oil prices by the World Bank, the expected CPO demand in biodiesel production was studied. The simulation results show that, under the business-as-usual scenario, CPO demand for biodiesel production exhibits decline from 591,000 mt in 2014 to 494,618 mt in 2025 due to increases in CPO prices relative to that of crude oil. This is consistent with Mekhilef, Siga, and Saidur's (2011) findings which showed that crude palm oil as a feedstock for the future of biodiesel industry can be disadvantages for Malaysia when the CPO prices are too high thus escalating other oil prices in the commodity market in addition to low profit margin since 90% of the production cost has to be allocated for the palm oil feedstock and the measures by the Malaysian government to devote 40% of the total palm oil production for biodiesel production. Under scenario I, blend 10 and 15 of biodiesel was introduced into the model, which refers to a blend of 10% and 15% of palm methyl ester and 90% and 85% petroleum based diesel respectively. The simulation results show that CPO demand for biodiesel production increases to about 1.0 and 1.45 mn mt in 2015, suggesting 49% and 66% increase in CPO demand for biodiesel production respectively (Figure 10).

Figure 10: Simulation result for Scenario I (‘000 MT), 1982-2025



Source: Authors’ estimation.

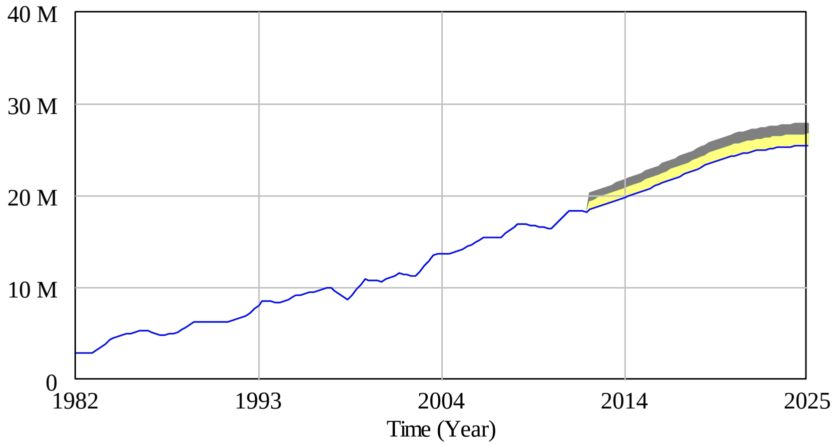
As the demand for palm oil rises, an increase in productivity gain can help improve the stability of CPO price. There is a potential increase in the FFB yield. Currently, there is a significant yield variation between plantations, smallholders as well as mills in Malaysia. Over the last decades, the average FFB yield is estimated between 19 and 21 mt per hectare a year. Lack of exposure to best practices and the insufficient economies of scale are the main factors resulting in inefficient crop yield across the nation (ETP, 2014). The simulation results show that, under the business as usual scenario, the CPO production is expected to increase from 19.56 mn mt in 2014 to 25.33 mn mt in 2025. Under scenario II, an increase in FFB yield by an average of 22 and 23 mt hectare a year is assumed. The simulation results show that the CPO production rises to 26.68 and 27.8mn mt, suggesting about 5% and 9% productivity increase respectively (Figure 11).

Biodiesel production in Malaysia is largely dependent on CPO production and Malaysia needs policies for development strategies of biodiesel production for coming years to meet demand. Findings of this study suggest the following overall policy implications:

- Palm oil is a major source of sustainable and renewable raw material for the biofuel industry in the world, with Malaysia and Indonesia having the potential to capture the biggest market shares. However, the biodiesel production in Malaysia is significantly under developed. For biodiesel production to remain viable, CPO price must decline further.

- The competitiveness of palm oil implies that it will remain as an important source of renewable raw material for biofuel industries in the future. Moreover, productivity gains in the palm oil industry have a significant impact on economic growth. Hence, it is important to increase efficiency in CPO production.
- The FFB yields can be improved through initiatives that enhance labour productivity in plantations. For instance, the harvesting process should rely more on motorised equipment rather than manual labour who are currently the main harvesting source. The government should enforce policies to monitor the FFB acceptance process by mills to make sure that only good quality crops are processed. Technological advances will help to raise yields and maximise oil production.

Figure 11: Simulation result for Scenario II ('000 MT), 1982-2025



Source: Authors' estimation.

7. Conclusion

This paper had investigated CPO production as well as CPO demand trends for biodiesel production in Malaysia using a simulation model. The model has been simulated for 44 years from 1982 to 2025 and the outputs indicate that the advent of B10 and B15 of biodiesel production will increase the CPO demand for biodiesel by 49% and 66% respectively. The results also indicate that there is a potential for increase in the FFB yield and CPO production in Malaysia with sufficient subsidy and R&D investment for. To motivate the farmers to adopt good practices, subsidies are required to minimise labour cost and non-labour inputs in addition to offering them good training programmes.

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